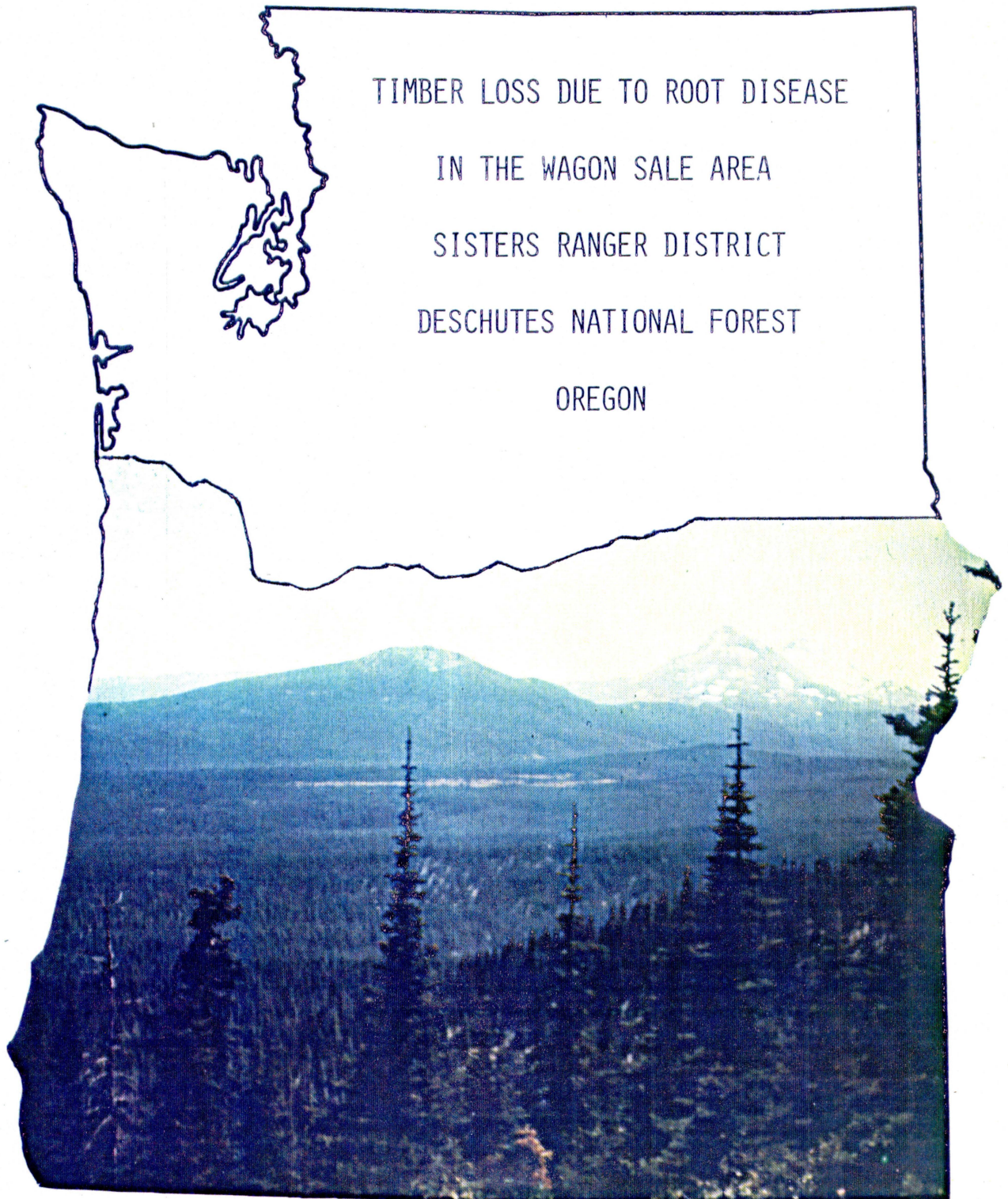


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Forest Insect & Disease Management Pacific Northwest Region



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TIMBER LOSS DUE TO ROOT DISEASE IN THE WAGON SALE AREA
SISTERS RANGER DISTRICT
DESCHUTES NATIONAL FOREST, OREGON

by

Gregory M. Filip

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ABSTRACT

Timber loss due to root disease-caused tree mortality was measured over a 2,500-acre area in the Wagon Timber Sale. Of a mean of 149.6 trees per acre over 5 in. DBH, 19.0%, representing 21.8% of the merchantable board foot volume, had been killed by root disease during the last 20 years. About a quarter of the dead trees were salvaged. Principal root diseases involved were Armillaria root rot in grand fir and ponderosa pine, laminated root rot in grand fir, and black stain root disease in ponderosa and lodgepole pine. A management scheme based on favoring relatively disease-tolerant species, as indicated by the survey data, may be the only viable alternative to reduce mortality caused by root disease in the entire 2,500 acre sale area.

INTRODUCTION

Tree mortality caused by root disease constitutes a major drain on productivity in Pacific Northwest forests. East of the Cascade Range, loss is most serious in the mixed-conifer (*Pinus-Pseudotsuga-Libocedrus-Abies*) zone. Volume loss due to tree mortality caused by Armillaria root rot has been recorded at 35 ft³/acre/year on 1,500 acres in south-central Washington (Shaw et al 1976) and 50 ft³/acre/year on 575 acres on the Winema National Forest, Oregon (Filip 1977). Loss caused by laminated root rot in eastside forest types is equally devastating. Practically all conifer species are susceptible to Armillaria root rot or laminated root rot although various degrees of disease resistance exist, especially in the latter case (Hadfield and Johnson 1977, Filip and Schmitt 1978).

The fungi that cause Armillaria and laminated root rots persist in infected root systems of both living and dead trees and can remain infective for decades. These disease-causing fungi spread primarily underground via root contacts, grafts, and, in the case of Armillaria, by black, root-like rhizomorphs. Large areas of concentrated tree mortality result from several decades of root infections, and disease spread.

Large disease centers often are associated with sites having a history of selective logging or salvage operations aimed at removing large diameter, merchantable timber, especially ponderosa pine. Infections of Armillaria root rot can remain dormant for years on lateral roots and taproots of living pines without causing above-ground symptoms, especially on large-diameter trees. When trees are harvested, the fungus quickly colonizes the root system, produces rhizomorphs and infects surrounding understory trees.

A third root malady called black stain root disease is caused by the fungus, *Ceratocystis (Verticicladiella) wagneri*. In Oregon and Washington, it has been found causing mortality primarily in second-growth Douglas-fir west of the Cascade Range (Goheen and Hansen 1978). However, in California ponderosa pine serves as the primary host, and extensive damage has been reported (Byler et al 1979).

Black stain root disease is transmitted initially by certain root feeding insects, and subsequently, like other root diseases, spreads by root contact from tree to tree. Unlike other root diseases, however, the fungus does not persist in dead trees and dies with the host. Prior to this survey, black stain root disease had not been found extensively in ponderosa or lodgepole pine in Oregon or Washington. Its frequent occurrence in ponderosa pine may alter the normal silvicultural management of that species in the Wagon Sale Area.

Annosus root rot caused by *Fomes annosus* occasionally causes tree mortality in Oregon and Washington. Damage more frequently occurs as a root and butt rot of hemlock or true fir. Occasionally, young ponderosa pines are killed by *Fomes annosus*.

OBJECTIVES

Objectives of this evaluation were to:

- (1) Determine stocking, volume, and basal area losses due to root disease and other causes of tree mortality over the 2,500-acre sale area.
- (2) Develop management alternatives based on data collected from the survey to reduce present and future mortality caused by root disease.

METHODS

1. Area Description

The evaluation was done in the proposed Wagon Sale Area on the Sisters Ranger District, Deschutes National Forest, Oregon, near the northeast boundary of the Mt. Washington Wilderness--T. 13 S., R. 8 E., sec. 3, 9, 10, 14, 16 (Fig. 1). The area surveyed contains stands that are primarily uneven-aged (ave. age = 110 years) and are composed of several conifer species: grand fir (*Abies grandis*) and ponderosa pine (*Pinus ponderosa*) dominate with lesser amounts of lodgepole pine (*P. contorta*), noble fir (*A. procera*), Pacific silver fir (*A. amabilis*), western white pine (*P. monticola*), and Douglas-fir (*Pseudotsuga menziesii*).

Site class of the area is III-IV (Site Index 80-90, base 100 years). Elevation ranges from 4,000 ft. (Block 5) to 5,200 ft. (Block 1). Annual precipitation ranges from 30 inches at lower elevations to over 40 inches at higher elevations. The survey area has a history of repeated, often annual, salvage harvests aimed primarily at liquidating high-mortality-risk ponderosa pine. Along with fire exclusion policies and a chronic gopher problem, pine salvage operations have resulted in a gradual species conversion from pine to grand fir.

2. Area Delineation

The 2,500-acre Wagon Road Sale area was divided into 5 blocks of approximately 500 acres each to facilitate the survey (Figure 2). Each block was surveyed by walking transects in a north-south direction (except Block 1 where east-west transects were used). Transect lengths were determined from a map, and width between transects was 10 chains (660 feet).

3. Plot Establishment

Plots were located every 2 chains (132 ft.) along transects. Plots consisted of a variable plot (BAF 20) and a fixed-area circular plot (1/100 acre). Plot centers were the same for both variable and fixed plots. Only trees greater than or equal to 5.0 in. DBH were measured on variable plots. Trees less than 5.0 in. DBH but greater than or equal to 6 in. in height were measured on fixed-area plots.

Variable plots were classified as either healthy--no dead or harvested trees within plot; diseased--at least one dead or harvested tree within plot; or nonstocked--no living, dead, or harvested trees within plot.

All diseased plots were measured. Because homogeneity was assumed to be greater among trees in healthy plots, only a sample (one out of three) of healthy plots was measured.

4. Data Collection

The following data were collected for each plot tree: (1) tree species, (2) DBH (approximated for stumps), (3) cause of infection or mortality, and (4) tree condition: live standing, windthrown, recently killed (0-5 years), snag (dead 6-10 years), stub (dead 11-20 years), or stump (harvested tree). Trees or stumps with less than half of their circumference with intact bark at the root collar were considered dead for more than 20 years and were not recorded.

Root diseases were detected by chopping at the root collar and by limited excavation and dissection of roots near the root collar. Only dead or nearly dead trees or stumps were examined for root disease. No attempt was made to record possible root infection of living trees. Armillaria root rot was detected by the presence of mycelial fans beneath the bark (Figure 3) or by yellow, stringy decay in old, dead material. Laminated root rot was detected by the presence of ectotrophic mycelium on the surface of exposed roots or by characteristic laminated decay with setal hyphae in old, dead material (Figure 4). Annosus root rot was detected by the presence of white, stringy decay in old, dead material. Black stain root disease was detected by the presence of brown-black stain in the sapwood of infected trees (Figure 5) and by culturing stained wood on agar media.

Stand volume tables were constructed from tree diameters and heights collected from a range of diameter classes within each tree species and from form class data obtained from District personnel.

5. Block Map Construction

Following data collection, maps were constructed for each block showing the location of plots that were either healthy or diseased and the cause(s) of mortality or infection.

6. Computer Analysis

All data were tabulated by computer using the Region 6, FIDM V-Plot Program specifically designed to tabulate insect and disease survey data (GREGG 1977). The program allowed the variable plot data to be tabulated by: (1) block number and tree condition, cause of mortality, or years since death, (2) tree species and tree condition, cause of mortality, or years since death, and (3) diameter class and tree condition. Data were expressed as trees per acre, basal area per acre, cubic feet per acre, and board feet per acre. Cubic foot volumes were calculated by 16-foot logs to a 4 inch top and board-foot volumes by 16-foot logs to a 5-inch top. Trees with board foot volumes less than 10 were computed as zero.

RESULTS AND DISCUSSION

I. Data for Entire Area

(1) Plot Data

Approximately 2,500 acres were surveyed with 1,381 variable-fixed plots (one plot per 1.8 acres). A crew of two completed the entire survey in 6 weeks. Of 1,381 plots, 535 (38.8%) were healthy (no dead or harvested trees ≥ 5 in. DBH present), 836 (60.5%) were diseased (at least one dead or harvested tree ≥ 5 in. DBH present), and 10 (0.7%) were nonstocked (no trees ≥ 5 in. DBH present, living, dead, or harvested).

(2) Tree Condition

Of a mean 149.6 trees per acre over 5 in. DBH, 19.0% representing 21.8% of the merchantable board foot volume had been killed by root disease during the last 20 years (Table 1). Another 6.8% of the trees, representing 6.7% of the board foot volume had been killed by other causes (bark beetles, flat-headed borers, balsam woolly aphids, suppression, other minor root diseases) or were too old to determine the cause (possibly root disease). Many trees, particularly grand firs with root disease, were also infested by fir engravers (*Scolytus ventralis*).

About a quarter of the dead trees, representing almost two-thirds of the board foot volume, had been harvested. According to District personnel, only dead or dying trees were harvested, which indicates that most if not all were infected with root disease prior to cutting. It is assumed that any living infected trees that were harvested would have died by the time this evaluation was done.

Almost half of the standing mortality has been dead for 6-10 years and another 15.6% for 11-20 years (Table 3). Hence, most of the remaining standing mortality, especially grand fir, is probably too deteriorated to salvage. About 1.7% of the trees have been windthrown in the past 20 years. It could not be determined whether the windthrown trees fell before or after they died. All windthrown trees had root disease, however.

Of a mean 173.0 seedlings (0.0-0.9 in. DBH) per acre, 3.9% were infected and killed by root disease (Table 5). Another 4.5% were killed by other causes. Of 35.7 saplings (1.0-4.9 in. DBH) per acre, 13.2% were infected and killed by root disease, and another 7.0% were killed by other causes. Since mortality was recorded for a 20 year period, many of the dead trees, especially seedlings, may have disintegrated beyond recognition and, thus, could not be detected. In lightly stocked areas, seedling and sapling mortality will reduce the number of potential crop trees.

(3) Causal Agents of Root Disease

Approximately 40.5% of the dead trees ≥ 5 in. DBH, representing 48.9% of the board foot volume, were killed by Armillaria root rot caused by *Armillaria mellea* alone (Table 7). Armillaria root rot accounted for another 3.6% of the mortality in association with black stain root disease caused by *Ceratocystis wagenerii* and another 3.6% in association with laminated

root rot caused by *Phellinus weirii*. Approximately 19.7% of the mortality representing 12.1% of the board foot volume was caused by laminated root rot alone, and about 4.1% of the mortality representing 4.5% of the board foot volume was caused by black stain root disease alone. Only 1.6% of the mortality representing 2.3% of the board foot volume was infected by *Fomes annosus* alone. Most of this occurred in old-growth stumps of harvested grand fir. No standing tree mortality was attributed to *Fomes annosus*, although some of the grand fir that were harvested may have been killed by *F. annosus* prior to cutting.

(4) Tree Diameter-Mortality Relationships

As mentioned previously, 3.9% of the seedlings and 13.2% of the saplings were infected and killed by root disease. In the 5.0-10.9 in. DBH category, 16.5% of the trees representing 15.8% of the board foot volume were infected and killed by root disease (Table 9). Another 7.2% of the trees in this size class were killed by other causes. In the 11.0-20.9 in. class, 22.9% of the trees representing 23.0% of the board foot volume were killed by root disease. Another 6.8% of the trees in this size class were killed by other causes. In the 21.0 in. and over size class, 22.4% of the trees representing 21.7% of the board foot volume were infected and killed by root disease. Another 4.9% of the trees were killed by other causes.

In summary, it appears that incidence of mortality caused by all root diseases in all tree species is least in seedlings, increases in the sapling and pole classes, and is greatest in trees of 11 inch DBH and over. Apparently, it takes several years for seedlings to contact buried root disease inoculum before infection occurs. Mortality results when root infections reach the root collar. Larger trees may have root infections for several years before the root collar is attacked and the trees are killed, especially with *Armillaria* root rot. Windthrow may occur before tree mortality.

(5) Species-Mortality Relationships

Seven conifer species were recorded in the area surveyed. Grand fir was the dominant species--41.3% of the stocking $\geq$ 5 in. DBH--but represented only 23.1% of the board foot volume. Although ponderosa pine represented only 27.7% of the stocking, it comprised 65.8% of the board foot volume. Lodgepole pine and other true firs (Pacific silver fir and noble fir) were also present with small amounts of Douglas-fir and western white pine. Data for noble and Pacific silver firs were combined because the species were difficult to distinguish in the field and hybridization may have occurred.

Grand fir exhibited the most mortality caused by root disease at 24.1% of the stocking and 29.0% of the board foot volume (Table 2). Less than half of this mortality (volume) had been salvaged. Ponderosa pine was second with a loss of 20.5% of the stocking and 20.0% of the board foot volume, but nearly three-fourths of the volume had been salvaged. Douglas-fir and lodgepole pine appeared more resistant to root disease than grand fir and ponderosa pine, but mortality increased in the larger diameter

classes as exhibited by differences in percentage of stocking and volume killed by root disease within these species. White pine, on the other hand, appeared to be more susceptible to root disease in the smaller diameter classes, and mortality was less frequent in larger diameter trees. Other true firs appeared to be more resistant to mortality than either grand fir or ponderosa pine, and mortality was relatively constant through all diameter classes.

For all species, most of the standing mortality was 6-10 years old, except for Douglas-fir, where most of the mortality was older than 10 years (Table 4). Grand fir, followed by lodgepole pine, appeared to be windthrown most frequently. Also, other true firs of large diameter appeared to windthrow frequently.

About a third of the grand fir mortality was caused by Armillaria root rot alone and another third by laminated root rot alone (Table 8). Presence of both of these diseases on a single tree was also observed (5.3% of mortality). Over half of the ponderosa pine mortality was caused by Armillaria alone and another 11.3% of the mortality by Armillaria in association with black stain root disease. Black stain root disease alone accounted for 12.3% of the mortality representing 6.5% of the board foot volume. This indicates that the smaller diameter ponderosa pines were killed more frequently by black stain root disease than the larger trees. More than half the other true fir mortality was caused by Armillaria root rot with lesser amounts of mortality associated with laminated root rot alone or laminated root rot in association with Armillaria root rot. Over a third of the lodgepole pine mortality was caused by Armillaria root rot with lesser amounts of mortality caused equally by other root diseases or disease complexes. More than half of the Douglas-fir mortality was caused by laminated root rot, while more than half of the white pine mortality was caused by Armillaria root rot.

II. Data by Blocks

Block 1

(1) Plot Data

Block 1, the highest elevation surveyed, was composed primarily of grand fir--50.8% of the stocking and 50.2% of the board foot volume. It was also the only block with significant amounts of white pine--6.4% of stocking and 6.5% of board foot volume. Of 327 plots used to survey Block 1, 64 (19.6%) were healthy, 260 (79.5%) were diseased, and 3 (0.9%) were nonstocked. Block 1 was the most diseased. The large component of grand fir in the stand and the high susceptibility of this species to both Armillaria root rot and laminated root rot contributed to the severe disease situation in Block 1. Other true firs and white pine appeared to be more resistant to root disease in this block.

(2) Tree Condition

A larger proportion of trees were killed by root disease in Block 1 than in any other block (Table 1). The percentage of volume killed by root disease was second only to Block 3. The lowest percentage of dead tree

volume was harvested in Block 1, probably due to the low relative merchantability of grand fir and the steep topography in the Block. Only about half of the standing dead volume was harvested.

Block 1 had the lowest proportion of recent tree mortality (1-5 years) of any block (Table 3). The reason for this is unknown.

A higher percentage of saplings were killed by root disease in Block 1 than in any other block, again probably due to the high component of grand fir (Table 5). The percentage of seedlings killed by root disease was second only to Block 5.

(3) Causal Agents of Root Disease

Most of the tree killing in Block 1 was caused by laminated root rot, but most of the volume loss was caused by Armillaria root rot. Apparently, laminated root rot is affecting a smaller size class than Armillaria root rot. Appearance of both root diseases on the same tree was most common in this Block. More trees were classified as "killed by other causes" in this Block, probably because dead grand fir deteriorates rapidly, making identification of mortality-causing agents quite difficult.

Block 2

(1) Plot Data

Most of Block 2 is high elevation, and, like Block 1, has a large component of grand fir (51.8% of stocking). However, the majority of the wood volume is in ponderosa pine (65.5%), especially along the lower part of the block. Of 288 plots used to survey this block, 146 (50.7%) were healthy, 140 (48.6%) were diseased, and 2 (0.7%) were nonstocked.

(2) Tree Condition

Percentage of trees and volume lost due to root disease were lower in Block 2 than in Block 1, probably due to the lower volume complement of grand fir and the lower frequency of laminated root rot (Table 7). Other true firs, white pine, and small diameter lodgepole pine appeared more resistant to root disease than ponderosa pine or grand fir.

Unlike Block 1, 65% of the standing dead volume, most of which was ponderosa pine, had been harvested.

Block 2 had the greatest proportion of recent mortality on a volume basis and was second on a stocking basis (Table 3). Again, the reason for this is unknown.

(3) Causal Agents of Root Disease

Over half of the mortality and volume loss in Block 2 was caused by Armillaria root rot alone (Table 7). Another 8.4% of the total mortality representing 9.2% of the board foot volume was caused by Armillaria root rot in association with black stain root disease, most of which occurred

in ponderosa pine. Black stain alone accounted for 7.0% of the mortality representing 3.0% of the volume, primarily in ponderosa pine. Much of the laminated root rot in this block was associated with Armillaria root rot.

Block 3

(1) Plot Data

Block 3 is at a lower elevation than Blocks 1 and 2 and has a much higher component of ponderosa pine (41.7% of the stocking, 72.3% of the board foot volume). Of 267 plots used to survey Block 3, 111 (41.6%) were healthy, 153 (57.3%) were diseased, and 3 (1.1%) were nonstocked.

(2) Tree Condition

Percentage of volume killed by root disease was higher in Block 3 than in any other block; however, 79.0% of this volume, mostly ponderosa pine, has been salvage logged. Other true firs and small diameter lodgepole pine appeared more resistant to root disease than grand fir or ponderosa pine. As in other blocks, most of the mortality was over 5 years old.

(3) Causal Agents of Root Disease

Over half of the mortality was caused by Armillaria root rot alone (Table 7). Some mortality was caused by laminated root rot alone or in association with Armillaria root rot. More annosus root rot occurred in this block than in any other. However, most was found in old-growth grand fir stumps, and no standing mortality could be attributed to *F. annosus*. Most of the damage caused by *F. annosus* is probably butt rot of living grand firs.

Block 4

(1) Plot Data

Block 4 is at a lower elevation than most of the other blocks and has a large component of lodgepole pine--55.0% of the stocking--but large volumes of ponderosa pine representing 70.8% of the board foot volume. Of 280 plots used to survey Block 4, 115 (41.1%) were healthy, 164 (58.6%) were diseased, and 1 (0.3%) was nonstocked.

(2) Tree Condition

A lower percentage of trees were killed by root disease on this block than on any other, and the proportion of volume killed was also very low (Table 1). Also, a lower percentage of seedlings and saplings were killed by root disease in this block than in any other (Table 5). This is probably due to the very low component of grand fir (14.0% of stocking and 7.1% of board foot volume), the lowest of any block. Some of the mortality in lodgepole pine was due to mountain pine beetle (*Dendroctonus ponderosae*). More than half of the dead volume, mostly ponderosa pine, has been salvaged.

A higher percentage of dead trees, mostly lodgepole pine, were wind-thrown in this block than in any other (Table 3).

(3) Causal Agents of Root Disease

Most of the mortality in Block 4 was caused by Armillaria root rot alone or in association with black stain root disease. This block also had a high rate of tree mortality caused by black stain root disease alone, probably due to the large component of two susceptible species, lodgepole and ponderosa pine. Also, black stain root disease is most damaging in areas with high soil moisture, such as occurs in this block. Several living old-growth ponderosa pines were also infected with black stain root disease but were not recorded. Such trees often exhibit thin and off-color crowns (Figure 6).

Block 5

(1) Plot Data

Block 5 is also at low elevation but has a higher component of grand fir than Block 4. However, the largest volume component--82.4% of board foot volume--is of ponderosa pine, the highest of any block. Of 219 plots used to survey Block 5, 99 (45.2%) were healthy, 119 (54.3%) were diseased, and 1 (0.5%) was nonstocked.

(2) Tree Condition

This block had a lower percentage of volume killed by root disease than any other block, due to the low volume component of grand fir--16.0% of board foot volume (Table 1). More than half of the dead volume has been salvaged. Mortality was more recent in this block than in any other, mostly in the smaller diameter classes. A higher percentage of seedlings were killed by root disease in this block than in the others, mostly of grand fir. Also, the highest percentage of both seedlings and saplings killed by causes other than root disease occurred in this block.

(3) Causal Agents of Root Disease

Most of the mortality in Block 5 was caused by Armillaria root rot alone or in association with black stain root disease (Table 7). The highest percentage of mortality caused by black stain root disease alone occurred in this block, primarily in ponderosa pine. As in Block 4, this is due to the large component of ponderosa pine and the relatively moist soil conditions characteristic of the block.

SUMMARY AND CONCLUSIONS

The entire 2,500-acre Sale Area is experiencing a root disease epidemic involving several species of root pathogens. Most of the mortality is caused by Armillaria root rot, primarily in grand fir and ponderosa pine. Grand fir is also experiencing severe mortality caused by laminated root rot, primarily in high elevation areas. Ponderosa pine and lodgepole pine are experiencing some mortality due to black stain root disease, primarily in low elevation areas with high soil moisture. Complexes of two root diseases frequently occur in the same area and even on the same tree. Although noble fir, Pacific silver fir, lodgepole pine, white pine, and Douglas-fir are being killed by root disease, mortality is less frequent in these species than in ponderosa pine or grand fir.

Although growth loss due to root disease was not measured in this evaluation, it may be substantial, especially in trees affected with black stain root disease. Several living but infected pines were observed throughout the Sale Area, and such trees may be experiencing severe growth loss before they die or before they are harvested.

A management scheme based on favoring or planting on-site white pine (rust-resistant), noble fir, or Pacific silver fir in high elevation areas or Douglas-fir, lodgepole pine, or even ponderosa pine in low elevation areas may be the only viable alternative to reduce mortality caused by root disease in the present and future stand. Limited operations to remove infected stumps of diseased trees to reduce future tree mortality may be feasible on level sites with workable soils (Roth et al 1977, Roth et al 1980). Although periodic operations aimed at harvesting dead or dying trees will salvage wood that would normally be lost, the number of future trees attaining merchantability will continue to decrease rendering large areas unproductive unless sound silvicultural prescriptions are applied now.

The information and recommendations presented in this report have been formulated specifically for the area that we surveyed. Although some of this information may be applied to other areas in Oregon and Washington experiencing similar root-disease problems, these areas may be sufficiently different from the area we surveyed to warrant a separate biological evaluation to formulate management alternatives specific to that area. FIDM pathologists encourage and are available to perform such evaluations at the request of land managers.

MANAGEMENT ALTERNATIVES

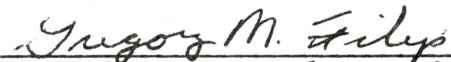
The following management alternatives for disease reduction are presented for the Wagon Sale Area in increasing order of cost and effectiveness of reducing root disease:

- (1) No treatment. Losses due to tree mortality will average 1.9 trees/acre/year representing 70 feet³/acre/year. Losses probably will remain constant if the forest is left undisturbed.
- (2) Continue current salvage program. Most of the volume loss sustained above will be captured. However, loss expressed as infected land area and infected trees per acre will increase, and the number of trees reaching merchantability will decrease. In some blocks, ponderosa pine may be eliminated as a significant component of the stand as a result of infection, mortality, and selective harvesting.
- (3) Seed tree or shelterwood systems discriminating against grand fir. Most of the merchantable timber will be harvested in one or a few operations. Future loss will decrease since grand fir is most susceptible to root disease. Scarification can be used to prepare a better seedbed for pines. Seedlings to be planted should be from a local seed source. Gopher control may be necessary to insure successful establishment of pine. In moist areas where black stain root disease is a problem, all trees should be killed or harvested and the area not planted for at least one year. If black stain root disease is present, it should die with its pine host within a year. After this fallow period, plant with any species besides grand fir.
- (4) Seed tree or shelterwood systems discriminating against grand fir with special selection of low disease-risk trees. Loss of leave trees will be decreased even further if special care is taken to mark leave trees that are low risk to root disease, based on their proximity to infected trees or stumps. In severely diseased areas with few species besides grand fir, such sites may resemble clear cuts after harvesting since so few low risk trees may remain. FIDM Staff can assist in training of marking crews to recognize low risk trees. Site preparation and planting should be as in Alternative 3.
- (5) Seed tree or shelterwood systems with special selection and stump removal. In addition to the benefits of alternative 4, this alternative will be the most effective in reducing infection and mortality in regeneration, including grand fir, and hence the future stand by removing the bulk of fungus inoculum from the soil. Stumps of infected trees are marked before cutting, and, after harvesting, marked stumps are excavated with heavy machinery. Costs on similar sites range from \$150-250 an acre to remove and pile stumps and prepare the site for planting. Forms submitted to FIDM for funding include Form 3400-2, Environmental Analysis Report, and a Cost/Benefit Analysis.
- (6) Combination of alternatives (2) through (5). Depending on land use objectives, site conditions, and stand characteristics, a combination of alternatives (2) through (5) may be used to reduce impact caused by root disease in the present and future stand.

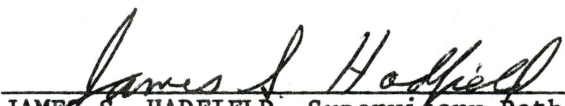
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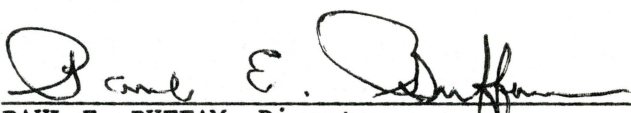
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DESCHUTES NATIONAL FOREST

0 MILES 15
0 KILOMETERS 30

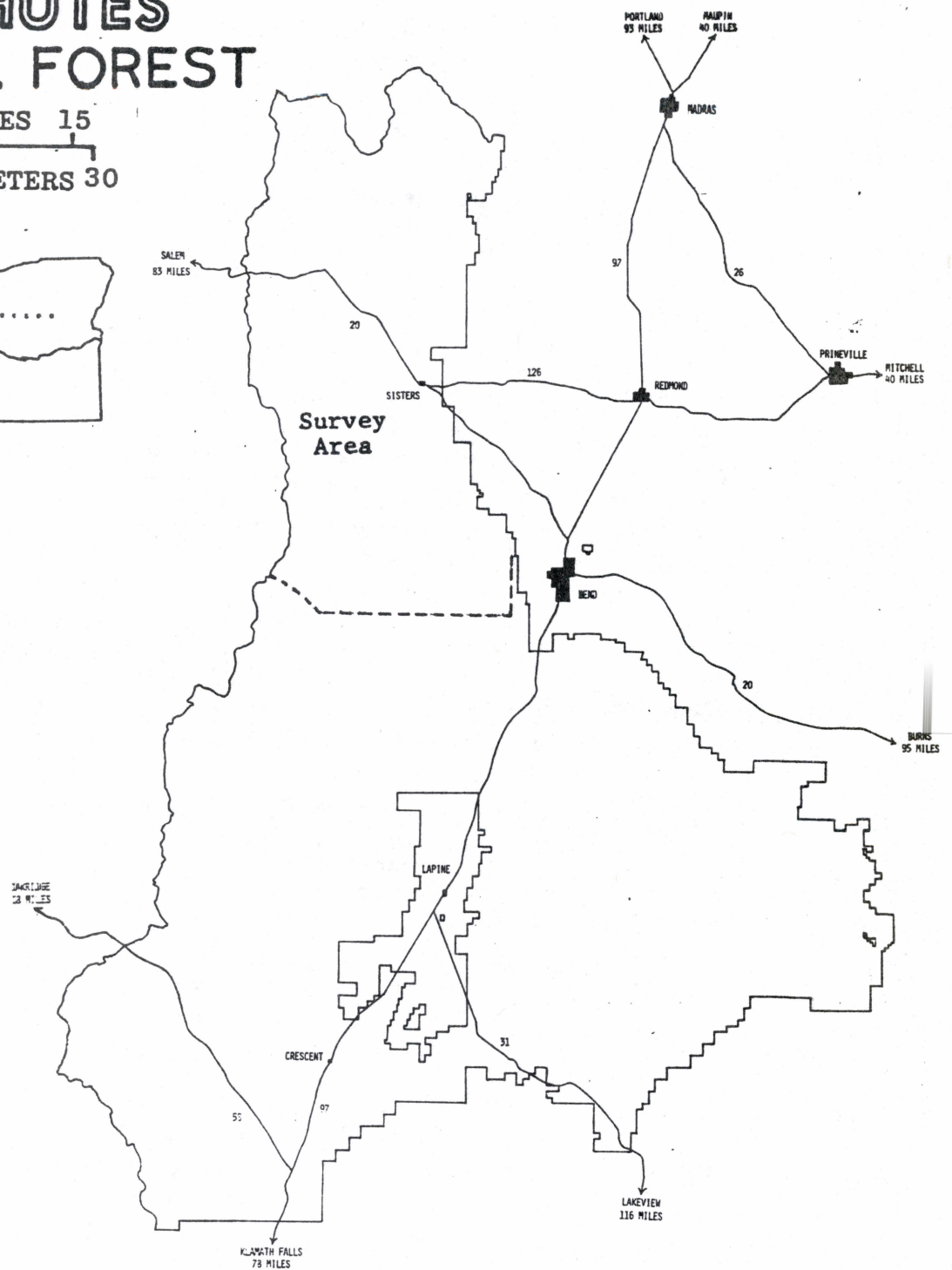


FIGURE 1--Map depicting area surveyed. Dotted line indicates southern boundary of the Sisters Ranger District.

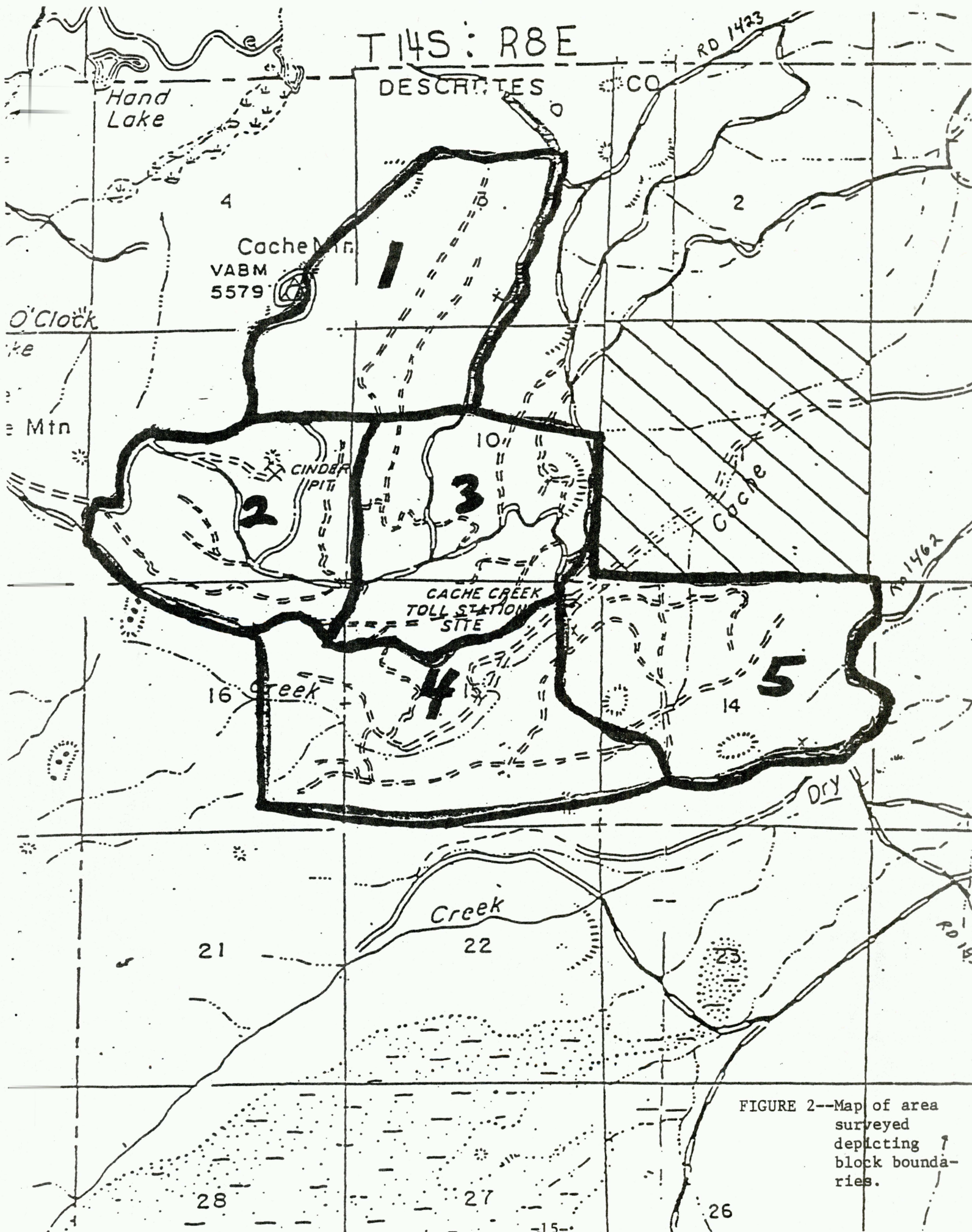


FIGURE 2--Map of area surveyed depicting 7 block boundaries.



FIGURE 3--Mycelial fans of *Armillaria mellea* beneath the bark of an infected ponderosa pine.



FIGURE 4--Laminated decay in grand fir caused by *Phellinus weirii*.



FIGURE 5--Stain in sapwood of a ponderosa pine infected with *Ceratocystis wageneri*.



FIGURE 6--Old-growth ponderosa pine infected with *Ceratocystis wageneri* showing crown symptoms. The tree on the left is healthy-appearing.

Table 1.--Stocking, basal area, and volume per acre of trees ≥ 5 in. DBH by block number and condition.

Block Number	Total	Healthy	Dead-Root Infected			Dead-Other Causes		
			Unharvested	Harvested	Total	Unharvested	Harvested	Total
			-----percent-----			-----		
1	170.7 ^a	67.1	20.6	2.5	23.1	8.8	1.0	9.8
	175.5 ^b	69.4	15.6	7.6	23.2	4.7	2.7	7.4
	5,561.3 ^c	69.5	13.6	9.8	23.4	3.8	3.3	7.1
	30,082.6 ^d	69.4	12.3	11.3	23.6	3.2	3.8	7.0
2	113.0	75.9	14.3	5.6	19.9	2.7	1.5	4.2
	152.1	75.9	9.9	10.2	20.1	1.4	2.6	4.0
	5,177.2	75.9	8.3	11.8	20.1	1.1	2.9	4.0
	29,587.9	76.0	7.5	12.5	20.0	0.9	3.1	4.0
3	133.4	74.1	9.6	9.0	18.6	3.4	3.9	7.3
	130.1	65.3	7.9	16.4	24.3	2.2	8.2	10.4
	4,477.3	64.3	6.9	18.1	25.0	1.7	9.0	10.7
	25,516.7	63.4	6.3	19.3	25.6	1.3	9.7	11.0
4	167.5	83.0	9.8	2.7	12.5	4.0	0.5	4.5
	133.5	76.8	8.4	9.6	18.0	3.7	1.5	5.2
	4,284.8	75.6	7.3	12.2	19.5	3.1	1.8	4.9
	23,884.6	75.1	6.6	13.7	20.3	2.6	2.0	4.6
5	150.7	78.4	14.3	4.2	18.5	1.8	1.3	3.1
	172.4	75.9	10.3	8.8	19.1	1.7	3.3	5.0
	5,713.5	74.8	9.3	10.1	19.4	1.7	4.1	5.8
	32,319.5	74.2	9.0	10.7	19.7	1.7	4.4	6.1
TOTAL	149.6	74.2	14.7	4.3	19.0	5.3	1.5	6.8
	154.4	72.1	11.3	10.0	21.3	3.2	3.4	6.6
	5,100.1	71.7	9.7	11.9	21.6	2.7	4.0	6.7
	28,632.4	71.5	8.8	13.0	21.8	2.3	4.4	6.7

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre

Table 2.--Stocking, basal area, and volume per acre of trees ≥ 5 in. DBH by tree species and condition.

Species	Total	Dead-Root Disease Infected				Dead-Other Causes		
		Healthy	Unharvested	Harvested	Total	Unharvested	Harvested	Total
		-----percent-----						
Grand fir	61.8 ^a	66.5	20.7	3.4	24.1	8.4	1.0	9.4
	47.1 ^b	66.2	19.5	7.2	26.7	5.2	1.9	7.1
	1,322.2 ^c	65.0	18.1	9.7	27.8	4.7	2.5	7.2
	6,623.4 ^d	64.0	17.4	11.6	29.0	4.0	3.0	7.0
Other firs ^e	14.3	83.2	9.8	1.4	11.2	5.6	<0.1	5.6
	8.3	83.2	9.6	2.4	12.0	4.8	<0.1	4.8
	201.5	82.1	10.3	2.7	13.0	4.4	0.5	4.9
	886.6	81.4	10.7	3.2	13.9	3.9	0.8	4.7
Douglas-fir	1.2	91.7	<0.1	8.3	8.3	<0.1	0.1	<0.1
	2.7	81.5	3.7	11.1	14.8	<0.1	3.7	3.7
	90.9	80.0	2.4	11.0	13.4	1.8	4.8	6.6
	528.8	78.4	2.3	12.1	15.4	1.8	5.4	7.2
Ponderosa pine	41.4	74.4	11.8	8.7	20.5	1.9	3.2	5.1
	79.5	72.7	7.1	13.7	20.8	1.5	5.0	6.5
	3,081.9	73.3	6.0	14.3	20.3	1.2	5.2	6.4
	18,846.4	73.6	5.5	14.5	20.0	1.1	5.3	6.4
White pine	1.0	80.0	20.0	<0.1	20.0	<0.1	0.0	<0.1
	1.3	94.6	7.7	7.7	15.4	<0.1	0.0	<0.1
	39.6	86.1	9.8	0.8	10.6	3.3	0.0	3.3
	195.9	87.0	9.2	0.4	9.6	3.4	0.0	3.4
Lodgepole pine	29.9	84.6	9.1	1.3	10.4	4.0	1.0	5.0
	15.5	77.4	11.0	3.9	14.9	5.8	1.9	7.7
	364.0	72.4	12.6	5.8	18.4	7.0	2.3	9.3
	1,551.3	68.3	13.4	7.9	21.3	7.6	2.8	10.4
TOTAL	149.6	74.2	14.7	4.3	19.0	5.3	1.5	6.8
	154.4	72.1	11.3	10.0	21.3	3.2	3.4	6.6
	5,100.1	71.7	9.7	11.9	21.6	2.7	4.0	6.7
	28,632.4	71.5	8.8	13.0	21.8	2.3	4.4	6.7

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre

^e Pacific silver and noble firs

Table 3.--Stocking, basal area, and volume per acre of dead or harvested trees
 ≥ 5 in. DBH by block number and years since death.

Block Number	Total Dead or Harvested	Standing dead				Wind- thrown	Harvested Trees
		Years since death					
		1-5	6-10	11-20	Total		
		percent					
1	56.2 ^a	0.5	36.4	8.8	45.7	4.5	49.8
	53.7 ^b	0.9	44.1	14.9	59.9	6.3	33.8
	1,696.3 ^c	0.9	36.3	14.4	51.6	5.5	42.9
	9,190.7 ^d	0.9	31.0	13.8	45.7	5.0	49.3
2	27.3	17.2	36.6	15.8	69.6	1.1	29.3
	36.7	10.6	24.3	9.8	44.7	1.9	53.4
	1,248.8	8.6	19.9	8.3	36.8	2.1	61.1
	7,114.4	7.5	17.7	7.6	32.8	2.2	65.0
3	34.6	6.1	30.3	13.6	50.0	0.6	49.4
	45.1	4.7	16.0	6.9	27.6	1.6	71.0
	1,598.1	4.0	12.4	5.6	27.0	1.8	76.2
	9,351.2	3.8	10.3	4.9	19.0	2.0	79.0
4	28.5	12.6	31.7	20.7	65.0	16.1	18.9
	31.0	5.5	21.3	14.8	41.6	10.3	48.1
	1,047.4	3.5	17.5	12.8	33.8	8.9	57.3
	5,946.8	2.6	15.0	11.5	29.1	7.9	63.0
5	32.5	19.1	36.4	13.8	69.3	5.5	25.2
	41.6	6.5	29.3	11.1	46.9	2.9	50.2
	1,438.5	4.5	27.1	10.0	41.6	2.3	56.1
	8,334.1	3.9	25.9	9.4	39.2	2.1	58.7
TOTAL	38.6	7.3	47.9	15.6	70.8	6.7	22.5
	43.2	4.4	30.8	12.0	47.2	4.9	47.9
	1,445.1	3.5	25.2	10.8	39.5	4.3	56.2
	8,150.5	3.3	19.4	11.6	34.3	4.5	61.2

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre

Table 4.--Stocking, basal area, and volume per acre of dead or harvested trees
>5 in. DBH by tree species and years since death.

Species	Total Dead or Harvested	Standing dead				Wind- thrown	Harvested Trees
		Years since death					
		1-5	6-10	11-20	Total		
----- percent -----							
Grand fir	20.7 ^a	6.8	57.0	14.0	77.8	9.2	13.0
	15.9 ^b	5.0	45.3	14.5	64.8	7.5	27.7
	463.1 ^c	4.0	38.9	15.1	58.0	7.0	35.0
	2,386.8 ^d	3.3	34.4	15.2	52.9	6.5	40.6
Other firs ^e	2.4	16.7	62.5	8.3	87.5	4.2	8.3
	1.4	21.4	50.0	7.2	78.6	7.1	14.3
	36.0	17.2	50.5	9.2	76.9	5.3	17.8
	164.5	16.1	46.3	9.6	72.0	6.3	21.7
Douglas- fir	0.1	0.0	<0.1	<0.1	<0.1	0.0	100.0
	0.5	0.0	<0.1	20.0	20.0	0.0	80.0
	18.2	0.0	8.3	12.6	20.9	0.0	79.1
	114.3	0.0	7.3	11.8	19.1	0.0	80.9
Ponderosa pine	10.6	5.7	26.4	17.9	50.0	2.8	47.2
	21.7	2.7	16.6	9.7	29.0	2.3	68.7
	821.8	2.6	14.1	7.8	24.5	2.5	73.0
	4,967.7	2.6	13.0	7.0	22.6	2.5	74.9
White pine	0.2	<0.1	50.0	0.0	50.0	0.0	50.0
	0.2	<0.1	100.0	0.0	100.0	0.0	<0.1
	5.5	23.6	70.9	0.0	94.5	0.0	5.5
	25.5	24.7	72.6	0.0	97.3	0.0	2.7
Lodgepole pine	4.6	8.7	50.0	21.7	80.4	6.5	13.1
	3.5	5.7	45.7	17.1	68.5	8.6	22.9
	100.5	3.3	44.1	16.7	64.1	6.9	29.0
	491.7	2.4	41.9	15.7	60.0	6.2	33.8
TOTAL	38.6	7.3	47.9	15.6	70.8	6.7	22.5
	43.2	4.4	30.8	12.0	47.2	4.9	47.9
	1,445.1	3.5	25.2	10.8	39.5	4.3	56.2
	8,150.5	3.3	19.4	11.6	34.3	4.5	61.2

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre

^e Pacific silver and noble firs

Table 5.--Stocking of seedlings and saplings by block number and condition.

Block Number	DBH	Total		Dead-Root	Dead-Other
	Class (in)	Trees per acre	Healthy	Infected	Causes
			- - - - -percent- - - - -		
1	0.0-0.9	108.8	83.5	10.1	6.4
	1.0-4.9	15.1	56.2	25.0	18.8
2	0.0-0.9	202.3	97.5	1.0	1.5
	1.0-4.9	40.3	78.2	16.8	5.0
3	0.0-0.9	85.9	90.7	1.2	8.1
	1.0-4.9	49.0	79.6	16.3	4.1
4	0.0-0.9	333.0	97.9	0.9	1.2
	1.0-4.9	60.8	91.7	5.0	3.3
5	0.0-0.9	142.1	77.4	10.6	12.0
	1.0-4.9	17.8	61.1	16.7	22.2
TOTAL	0.0-0.9	173.0	91.6	3.9	4.5
	1.0-4.9	35.7	79.8	13.2	7.0

Table 6.--Stocking of seedlings and saplings by species and condition.

Species	DBH	Total	Healthy	Dead-Root	Dead-Other
	Class (in)	Trees per acre		Infected	Causes
			- - - - -	-percent-	- - - - -
Grand fir	0.0-0.9	78.1	85.9	6.4	7.7
	1.0-4.9	12.2	64.4	23.0	12.6
Other ^a firs	0.0-0.9	10.9	98.7	0.0	1.3
	1.0-4.9	5.4	88.9	3.5	6.5
Douglas-fir	0.0-0.9	3.5	92.0	8.0	0.0
	1.0-4.9	0.0	0.0	0.0	0.0
White pine	0.0-0.9	1.5	100.0	0.0	0.0
	1.0-4.9	0.8	100.0	0.0	0.0
Ponderosa pine	0.0-0.9	39.1	93.4	2.8	3.8
	1.0-4.9	5.5	78.5	16.5	5.0
Lodgepole pine	0.0-0.9	39.9	97.7	1.1	1.2
	1.0-4.9	11.8	91.1	6.5	2.4
TOTAL	0.0-0.9	173.0	91.6	3.9	4.5
	1.0-4.9	35.7	79.8	13.2	7.0

^a Pacific silver and noble firs

Figure 7.--Stocking, basal area, and volume per acre of dead or harvested trees ≥ 5 in. DBH by block number and root disease.

Block Number	Total Dead or harvested	Root Disease Organisms Present							Other Causes
		<i>Armillaria</i> alone	<i>Phellinus</i> alone	<i>Fomes</i> alone	<i>Ceratocystis</i> alone	<i>Armillaria</i>	<i>Armillaria</i>	<i>Armillaria</i>	
						+ <i>Ceratocystis</i>	+ <i>Phellinus</i>	+ <i>Fomes</i>	
----- percent -----									
1	56.2 ^a	25.1	37.5	1.4	0.7	0.2	4.8	0.0	30.3
	53.7 ^b	33.7	33.9	1.1	1.3	0.2	5.0	0.0	24.8
	1,696.3 ^c	36.0	32.3	1.3	1.2	0.2	5.1	0.0	23.7
	9,190.7 ^d	37.4	31.4	1.5	1.4	0.2	5.1	0.0	23.0
2	27.3	56.4	0.7	0.4	7.0	8.4	8.1	1.8	17.2
	36.7	64.9	0.8	1.1	3.5	9.5	2.5	1.6	16.1
	1,248.8	66.0	0.7	1.4	3.1	9.2	1.1	1.6	16.9
	7,114.4	66.5	0.7	1.5	3.0	9.2	0.6	1.5	17.0
3	34.6	51.2	13.6	2.3	0.6	1.2	3.2	<0.1	27.9
	45.1	51.7	6.9	5.3	1.8	1.3	2.7	0.4	29.9
	1,598.1	52.0	5.4	6.1	2.2	1.4	2.3	0.6	30.0
	9,351.2	52.2	4.5	6.5	2.4	1.4	2.1	0.7	30.2
4	28.5	56.8	2.1	2.5	7.7	3.2	0.0	0.1	27.6
	31.0	61.0	0.3	1.6	7.4	6.5	0.0	0.6	22.6
	1,047.4	62.8	0.1	1.4	7.1	7.4	0.0	0.8	20.4
	5,946.8	64.1	<0.1	1.4	6.8	8.1	0.0	0.8	18.8
5	32.5	46.5	0.0	0.0	18.8	19.4	0.0	1.2	14.8
	41.6	40.9	0.0	0.0	16.1	21.6	0.0	0.2	21.2
	1,438.5	39.9	0.0	0.0	15.2	21.5	0.0	0.1	23.3
	8,334.1	39.7	0.0	0.0	14.6	21.4	0.0	0.1	24.2
Total	38.6	40.5	19.7	1.6	4.1	3.6	3.6	0.5	26.4
	43.2	47.0	14.6	1.9	4.4	5.3	2.8	0.5	23.6
	1,445.1	48.0	13.0	2.1	4.5	5.6	2.5	0.5	23.8
	8,150.5	48.9	12.1	2.3	4.5	5.8	2.3	0.5	23.6

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre

Table 8.--Stocking, basal area, and volume per acre of dead or harvested trees ≥ 5 in. DBH by tree species and root disease.

Species	Total Dead or harvested	Root Disease Organisms Present							Other Causes
		Armillaria alone	Phellinus alone	Fomes alone	Ceratocystis alone	Armillaria	Armillaria	Armillaria	
						+ Ceratocystis	+ Phellinus	+ Fomes	
-----percent-----									
Grand fir	20.7 ^a	33.3	32.9	1.0	0.0	0.0	5.3	0.5	27.0
	15.9 ^b	37.8	32.7	3.1	0.0	0.0	5.7	<0.1	20.7
	463.1 ^c	38.7	31.9	4.3	0.0	0.0	5.4	0.3	19.4
	2,386.8 ^d	39.7	31.0	5.2	0.0	0.0	5.3	0.3	18.5
Other firs ^e	2.4	50.0	4.2	0.1	0.0	<0.1	4.2	4.2	37.3
	1.4	57.1	7.1	<0.1	0.0	<0.1	7.1	<0.1	28.7
	36.0	52.8	8.3	1.1	0.0	1.9	5.6	2.8	27.5
	164.5	52.8	9.5	0.7	0.0	2.2	6.6	2.6	25.6
Douglas- fir	0.1	<0.1	100.0	0.0	0.0	0.0	<0.1	0.0	<0.1
	0.5	<0.1	60.0	0.0	0.0	0.0	<0.1	0.0	40.0
	18.2	7.1	50.0	0.0	0.0	0.0	4.9	0.0	38.0
	114.3	5.9	50.6	0.0	0.0	0.0	5.2	0.0	38.3
Ponderosa pine	10.6	50.9	2.8	0.9	12.3	11.3	0.9	<0.1	20.9
	21.7	55.3	1.8	0.9	7.4	9.7	0.9	0.5	23.5
	821.8	55.3	1.9	1.1	6.9	9.2	0.8	0.3	24.5
	4,967.7	55.6	2.0	1.2	6.5	9.0	0.7	0.4	24.6
White pine	0.2	50.0	<0.1	0.0	0.0	0.0	0.0	0.0	50.0
	0.2	100.0	<0.1	0.0	0.0	0.0	0.0	0.0	<0.1
	5.5	60.0	10.9	0.0	0.0	0.0	0.0	0.0	29.1
	25.5	60.0	11.0	0.0	0.0	0.0	0.0	0.0	29.0
Lodgepole pine	4.6	43.5	6.5	4.3	6.5	4.3	2.2	<0.1	32.7
	3.5	37.1	8.6	2.9	8.6	5.7	2.9	<0.1	34.2
	100.5	35.3	11.8	0.9	9.4	5.5	1.8	1.6	33.7
	491.7	34.0	14.0	0.4	9.4	5.8	1.7	1.8	32.9
TOTAL	38.6	40.5	19.7	1.6	4.1	3.6	3.6	0.5	26.4
	43.2	47.0	14.6	1.9	4.4	5.3	2.8	0.5	23.6
	1,445.1	48.0	13.0	2.1	4.5	5.6	2.5	0.5	23.8
	8,150.5	48.9	12.1	2.3	4.5	5.8	2.3	0.5	23.6

^a Trees per acre^b Basal area (ft²) per acre^c Cubic feet per acre^d Board feet per acre^e Pacific silver and noble firs

Table 9.--Stocking, basal area, and volume per acre of trees ≥ 5 in. DBH by size class and condition.

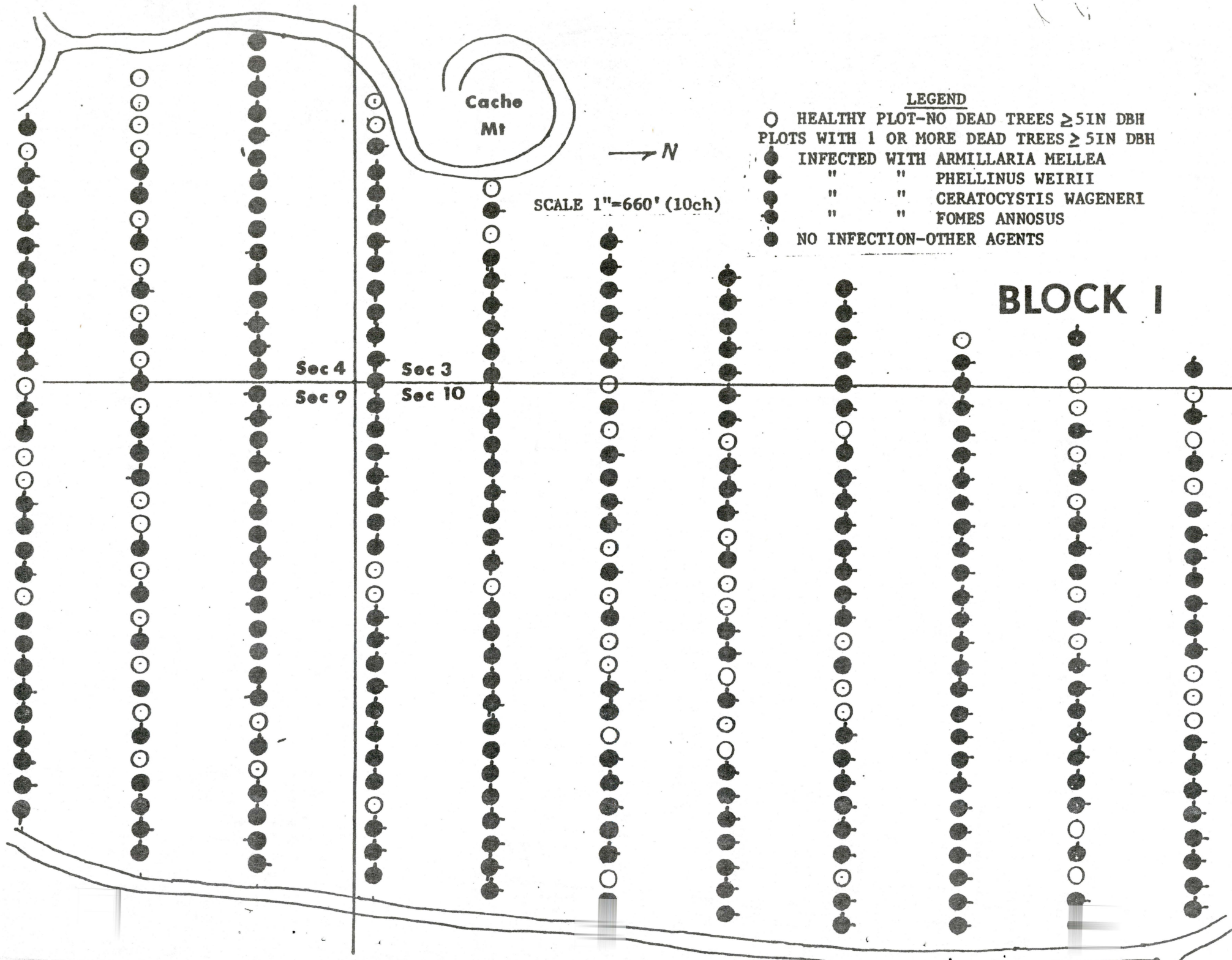
DBH Class (inches) Total		Healthy	Dead-Root Infected			Dead-Other Causes		
			Unharvested	Harvested	Total	Unharvested	Harvested	Total
-----percent-----								
5.0-	90.7 ^a	76.3	15.0	1.5	16.5	6.5	0.7	7.2
10.9	27.4 ^b	75.2	15.7	1.8	17.5	7.3	0.1	7.3
	455.3 ^c	74.8	14.7	1.4	16.1	8.7	0.4	9.1
	1,145.7 ^d	72.3	14.5	1.3	15.8	11.6	0.3	11.9
11.0-	42.4	70.3	17.2	5.7	22.9	4.7	2.1	6.8
20.9	52.9	70.3	16.4	6.2	22.6	4.3	2.6	7.0
	1,505.8	70.2	16.2	6.7	22.9	4.2	2.7	6.9
	7,468.4	70.1	16.1	6.9	23.0	4.1	2.8	6.9
21.0+	16.5	72.7	6.7	15.7	22.4	0.6	4.3	4.9
	74.1	72.2	6.1	15.7	21.8	0.9	5.1	6.0
	3,139.2	71.9	5.9	15.9	21.8	1.0	5.3	6.3
	20,018.3	72.0	5.8	15.9	21.7	1.0	5.3	6.3
TOTAL	149.6	74.2	14.7	4.3	19.0	5.3	1.5	6.8
	154.4	72.1	11.3	10.0	21.3	3.2	3.4	6.6
	5,100.1	71.7	9.7	11.9	21.6	2.7	4.0	6.7
	28,632.4	71.5	8.8	13.0	21.8	2.3	4.4	6.7

^a Trees per acre

^b Basal area (ft²) per acre

^c Cubic feet per acre

^d Board feet (Scribner) per acre



LEGEND

- HEAD PLOT-NO DEAD TREES ≥ 5IN DBH
- PLOTS WITH 1 OR MORE DEAD TREES ≥ 5IN DBH
- INFECTED WITH ARMILLARIA MELLEA
- " " PHELLINUS WEIRII
- " " CERATOCYSTIS WAGENERI
- " " FOMES ANNOSUS
- NO INFECTION-OTHER AGENTS

SCALE 1"=660' (10ch)

N
↑

Ginder
pit

RD 1315

Sec 9 10

Sec 16 15

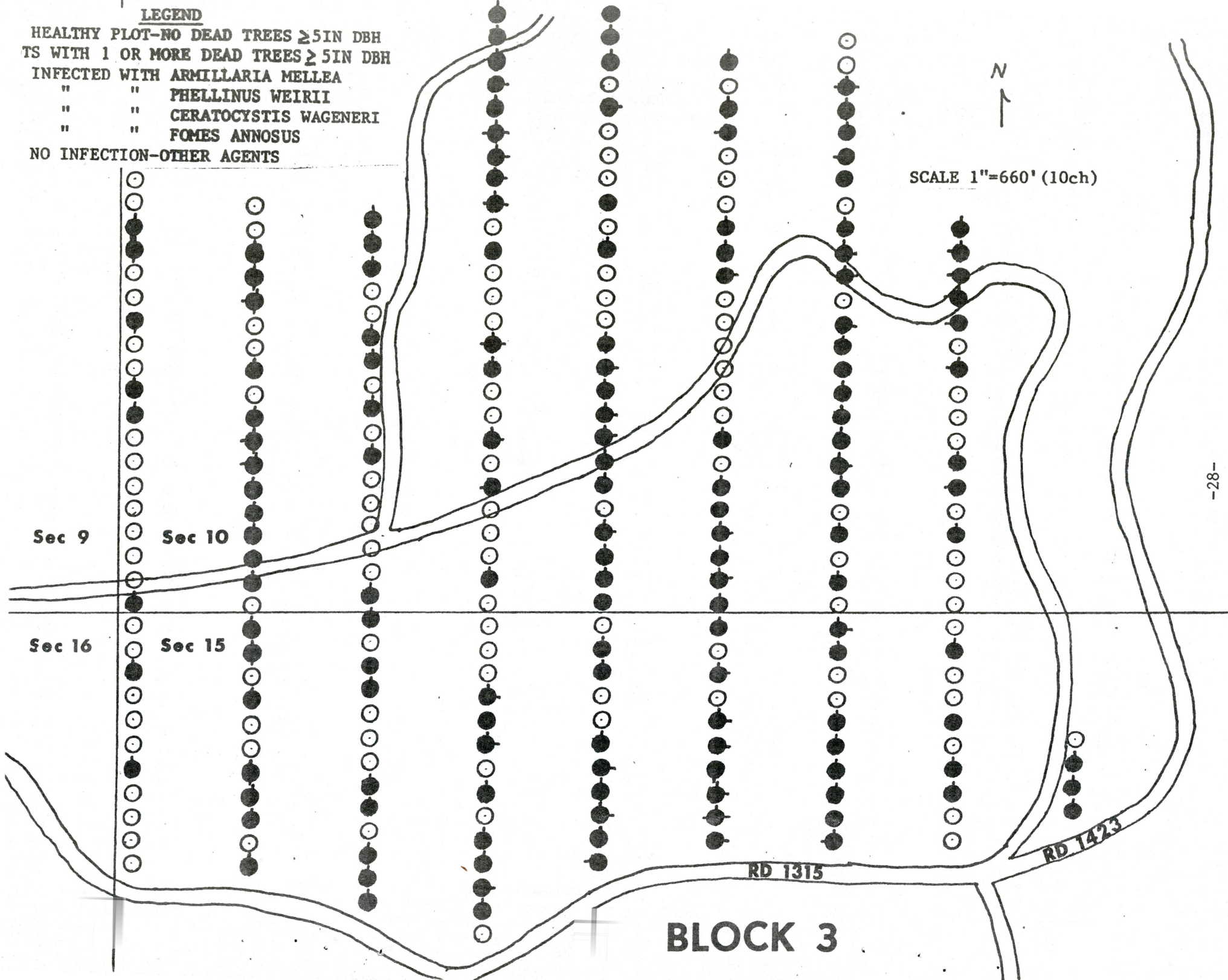
BLOCK 2

LEGEND

HEALTHY PLOT-NO DEAD TREES ≥ 5 IN DBH
TS WITH 1 OR MORE DEAD TREES ≥ 5 IN DBH
INFECTED WITH *ARMILLARIA MELLEA*
" " *PHELLINUS WEIRII*
" " *CERATOCYSTIS WAGENERI*
" " *FOMES ANNOSUS*
NO INFECTION-OTHER AGENTS

N
↑

SCALE 1"=660' (10ch)

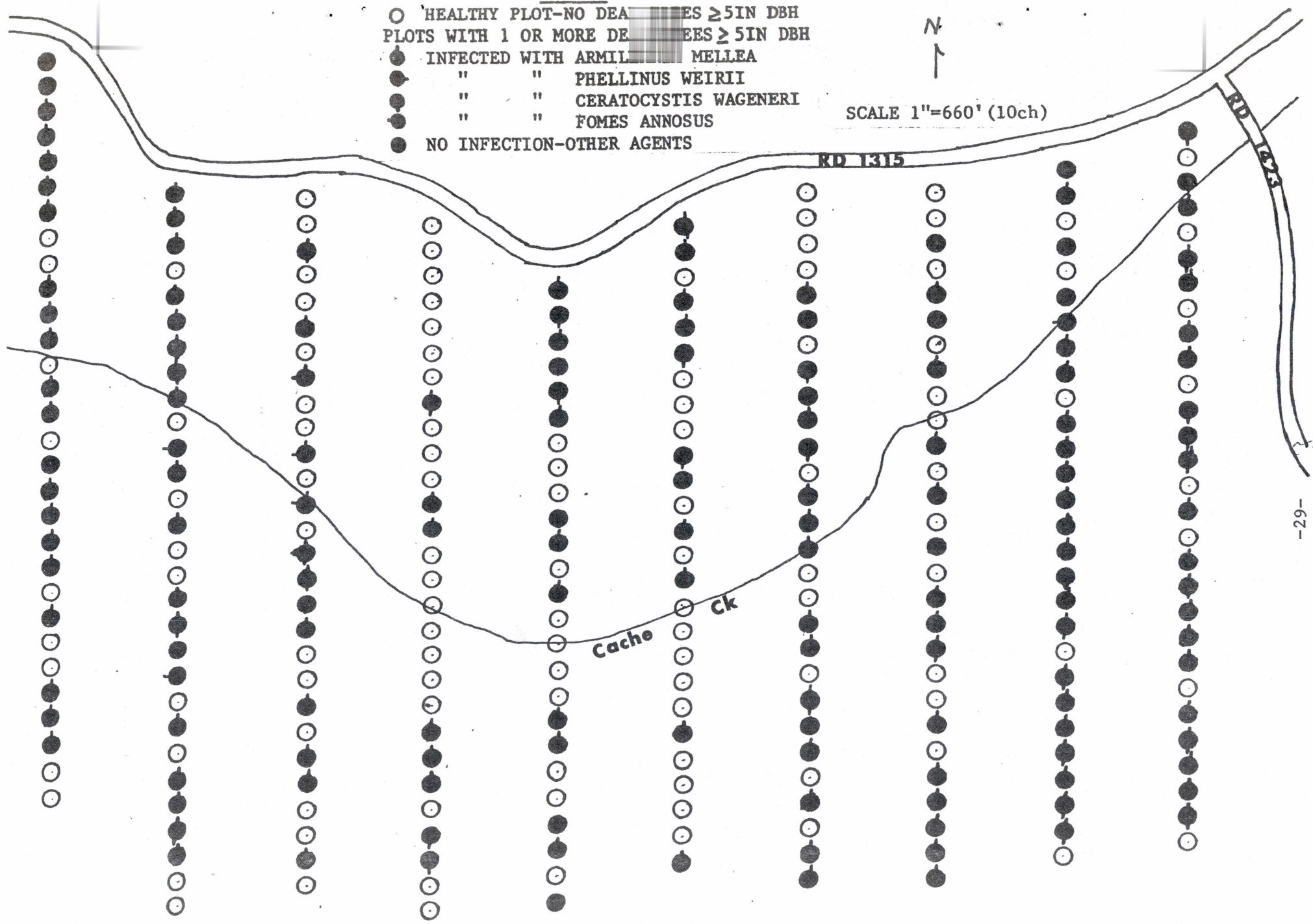


LEGEND

- HEALTHY PLOT-NO DEATHS ≥ 5IN DBH
- PLOTS WITH 1 OR MORE DEATHS ≥ 5IN DBH
- INFECTED WITH ARMILLARIA MELLEA
- " " PHELLINUS WEIRII
- " " CERATOCYSTIS WAGENERI
- " " FOMES ANNOSUS
- NO INFECTION-OTHER AGENTS

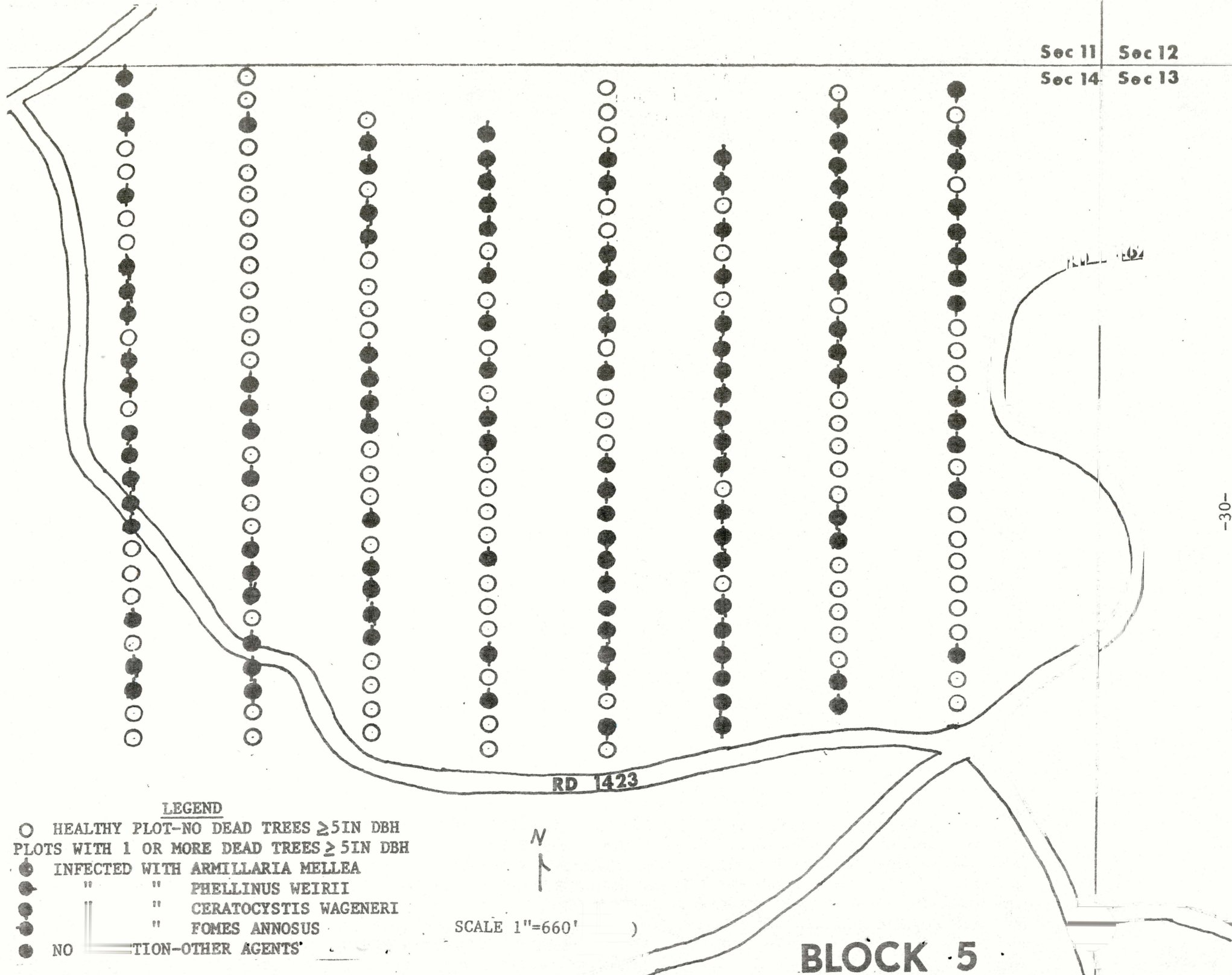


SCALE 1"=660' (10ch)



BLOCK 4

Sec 11 Sec 12
 Sec 14 Sec 13



LEGEND

- HEALTHY PLOT-NO DEAD TREES ≥ 5 IN DBH
- PLOTS WITH 1 OR MORE DEAD TREES ≥ 5 IN DBH
- INFECTED WITH ARMILLARIA MELLEA
- " " PHELLINUS WEIRII
- " " CERATOCYSTIS WAGENERI
- " " FOMES ANNOSUS
- NO " " TION-OTHER AGENTS



SCALE 1"=660'

BLOCK 5